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Short Communication

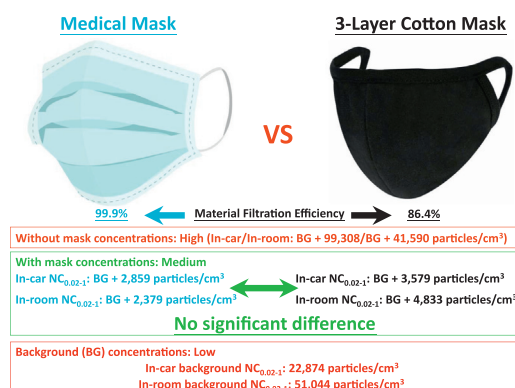
Medical mask versus cotton mask for preventing respiratory droplet transmission in micro environments

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HIGHLIGHTS

- The COVID-19 outbreak has led to a medical mask shortage around the world.
- Cotton mask can reduce respiratory droplet transmission in a bedroom or a car.
- No significant difference between medical and cotton mask for droplet prevention.
- Cotton mask could be a potential substitute for medical mask.
- Cotton mask is washable and reusable.

GRAPHICAL ABSTRACT



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ABSTRACT

The objective of this study was to investigate whether cotton mask worn by respiratory infection person could suppress respiratory droplet levels compared to medical mask. We recruited adult volunteers with confirmed influenza and suspected cases of coronavirus disease 2019 (COVID-19) to wear medical masks and self-designed triple-layer cotton masks in a regular bedroom and a car with air conditioning. Four 1-hour repeated measurements (two measurements for bedroom the others for car) of particles with a size range of 20–1000 nm measured by number concentrations (NC_{0.02-1}), temperature and relative humidity, and cough/sneeze counts per hour were conducted for each volunteer. The paired *t*-tests were used for within-group comparisons in a bedroom and in a car. The results showed that there was no significant difference in NC_{0.02-1} or cough/sneeze counts between volunteers with medical masks and cotton masks in a bedroom or a car. We concluded that the cotton mask could be a potential substitute for medical mask for respiratory infection person in microenvironment with air conditioning. Healthy people may daily use cotton mask in the community since cotton mask is washable and reusable.

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1. Introduction

The coronavirus disease 2019 (COVID-19) outbreak is a public health emergency of international concern (WHO, 2019). The Centers for Disease Control and Prevention (CDC) recommends that healthcare providers and those who might be infected wear masks but does not recommend the routine use of respirators in the community (CDC, 2020). However, people are racing to buy face masks, especially medical masks to protect themselves from infection (Secon, 2020). It has led to a medical mask shortage around the world and may result in shortage of medical mask for people in need (Miller, 2020). Previous studies have reported that oral cavity is the major sources of expiratory droplets in the range of 5–100 μm during speech and coughing (Johnson and Morawska, 2009). The infected person wear face mask can suppress the expired jets and reduce the close contact transmission via both the droplet-borne and short-range airborne routes of infectious agents in the indoor environment (Wei and Li, 2016). Moreover, it has been reported that towel (100% cotton) and common cloth (70% cotton and 30% polyester) masks showed 40–60% in filtration efficiency for polydisperse sodium chloride (NaCl) aerosol particles (75 ± 20 nm count median diameter (CMD) and a geometric standard deviation (GSD) not exceeding 1.86) at 5.5 cm/s face velocity (Rengasamy et al., 2010). Therefore, we conducted a panel study to investigate whether cotton mask worn by respiratory infection person could suppress respiratory droplet levels compared to medical mask in real micro environments.

2. Methods

We recruited 211 adult volunteers with 208 confirmed cases of influenza (influenza A = 188; influenza B = 17) and 6 suspected cases of COVID-19 from Taipei-Keelung metropolitan area, including Taipei City, New Taipei City, and Keelung City. All adult volunteers were required to wear medical masks (Earloop Procedure Face Mask 1820; 3M, MN, USA) and self-designed triple-layer cotton masks in a regular bedroom (11 ft by 12 ft) with an air conditioner in operation using outside air and a closed window located on the fifth floor of an apartment without any significant indoor and outdoor air pollution source in Taipei City, and in a TOYOTA VIOS powered by a gasoline engine with an air conditioner in operation using outside air and four closed windows located next to a park without any significant outdoor air pollution source in Taipei City from January 1, 2017 to February 20, 2020. Four repeated measurements of 1-hour mean particles with a size range of 20–1000 nm measured by number concentrations ($\text{NC}_{0.02-1}$) using a P-TRAK Ultrafine Particle Counter (model 8525; TSI Inc., MN, USA) located within 1 m around volunteer, 1-hour mean temperature and relative humidity by temperature and humidity sensor (model 1.153FH; Grimm Labortechnik Ltd., Ainring, Germany), and cough/sneeze counts per hour by voice recorder were conducted for each volunteer. Two repeated measurements (One with medical mask and the other one with cotton mask) were conducted in a bedroom and the other two repeated measurements were conducted in a car. The background concentrations of $\text{NC}_{0.02-1}$ in a bedroom and a car were measured 1 h before each formal repeated measurement. Moreover, the concentrations of $\text{NC}_{0.02-1}$ in a bedroom and a car

with volunteers without masks were also measured. We used one-way analysis of variance (ANOVA) with Scheffe's mean comparison test to compare the concentrations of $\text{NC}_{0.02-1}$ between background (without volunteer), without mask (volunteers wearing no mask), medical mask (volunteers wearing medical masks), and cotton mask (volunteers wearing cotton masks) in a bedroom and in a car. We further used paired *t*-tests for within-group comparisons between medical mask and cotton mask in a bedroom and in a car. The study protocol was approved by the joint institutional review board at the Taipei Medical University in Taipei, Taiwan (TMU-JIRB No. 201602045). Written informed consent was obtained from each volunteer before the study.

3. Results

The self-designed triple-layer cotton mask used in this study was simply made of 100% cotton layers. The filtration efficiency for particles with a size range of 20–1000 nm was measured by polydisperse NaCl aerosols (CMD = 75 nm; GSD = 1.83) which generated by an aerosol generator (model 3076; TSI, Inc., MN, USA) and passed through a dryer, an 85Kr neutralizer, and then into the Plexiglas box containing the test material. The size distribution of polydisperse NaCl aerosols was a log distribution of the left. The test was conducted by Taiwan Textile Research Institute. The test results showed that filtration efficiency were 86.4% and 99.9% at 5.5 cm/s velocity for our cotton mask and 3M medical mask, respectively. Our test result of 3M medical mask is comparable to 3M test results (>99% bacteria filtration efficiency) using MIL-M-36954C (3M, 2020).

The average age of the 211 adult volunteers was 41.4 years (SD = 2.4 years), the average BMI was 27.2 kg/m^2 (SD = 2.8 kg/m^2), and the male/female ratio was approximately 1:1. The mean concentrations of $\text{NC}_{0.02-1}$ for background (without volunteer), without mask, with medical mask, and with cotton mask were 51,044 particles/ cm^3 (SD = 15,913; $N = 211$), 92,634 particles/ cm^3 (SD = 62,844; $N = 211$), 53,423 particles/ cm^3 (SD = 17,525; $N = 211$), and 55,877 particles/ cm^3 (SD = 18,210; $N = 211$), respectively in a bedroom and 22,874 particles/ cm^3 (SD = 6998; $N = 211$), 122,182 particles/ cm^3 (SD = 79,554; $N = 211$), 25,733 particles/ cm^3 (SD = 9210; $N = 211$), and 26,453 particles/ cm^3 (SD = 9833; $N = 211$), respectively in a car. The mean concentrations of $\text{NC}_{0.02-1}$ for the volunteers wearing no mask were significantly higher than the background concentrations and the concentrations of $\text{NC}_{0.02-1}$ for the volunteers wearing medical masks or cotton masks in a bedroom (p -value < 0.05) and in a car (p -value < 0.05). There were no significant differences in $\text{NC}_{0.02-1}$ concentrations between background, volunteers wearing medical masks, and volunteers wearing cotton masks (Table 1).

According to the paired *t*-test results (Table 2), there were no significant differences in cough/sneeze counts, $\text{NC}_{0.02-1}$, temperature and relative humidity between volunteers with medical masks and cotton masks in a bedroom or a car. We further conducted paired *t*-test to compare the concentrations of $\text{NC}_{0.02-1}$ between without mask and background, and between background and with mask (medical mask and cotton mask, $N = 422$). The results showed that $\text{NC}_{0.02-1}$ concentrations for without mask were significantly higher than background in a bedroom (p -value < 0.01) and in a car (p -value < 0.01). There were no significant differences in $\text{NC}_{0.02-1}$ concentrations between background and with mask in a bedroom (p -value = 0.15) and in a car (p -value = 0.27).

Table 1

The within-group comparisons of $\text{NC}_{0.02-1}$ concentrations between background, without mask, medical mask, and cotton mask in a bedroom and in a car.

	Background	Without mask	Medical mask	Cotton mask	ANOVA	
					<i>p</i> -Value	Scheffe's test
Bedroom	51,044 \pm 15,913	92,634 \pm 62,844	53,423 \pm 17,525	55,877 \pm 18,210	0.04	W/B; W/M; W/C
Car	22,874 \pm 6998	122,182 \pm 79,554	25,733 \pm 9210	26,453 \pm 9833	0.03	W/B; W/M; W/C

Note: B = Background; W = Without mask; M = Medical mask; C = Cotton mask.

Table 2

Summary statistics and the within-group comparisons between the volunteers with medical masks and cotton masks.

	Medical mask	Cotton mask	Paired t-test p-Value
Gender, no.			
Male	102	102	–
Female	109	109	
Age, year			
Mean \pm SD	41.4 \pm 2.4	41.4 \pm 2.4	0.99
Range	35–59	35–59	
BMI, kg/m ²			
Mean \pm SD	27.2 \pm 2.8	27.2 \pm 2.8	0.99
Range	24.2–30.1	24.2–30.1	
In-room cough/sneeze counts per hour			
Mean \pm SD	16.3 \pm 1.2	17.9 \pm 1.2	0.76
Range	10–22	11–23	
In-room NC _{0.02–1} , particles/cm ³			
Mean \pm SD	53,423 \pm 17,525	55,877 \pm 18,210	0.25
Range	23,219–83,195	20,144–78,005	
In-room temperature, °C			
Mean \pm SD	25.4 \pm 2.0	25.3 \pm 2.2	0.82
Range	24.1–26.5	23.8–26.4	
In-room relative humidity, %			
Mean \pm SD	74.1 \pm 1.5	74.5 \pm 1.6	0.67
Range	69.2–76.5	68.4–74.3	
In-car cough/sneeze counts per hour			
Mean \pm SD	17.6 \pm 2.2	18.3 \pm 2.5	0.75
Range	14–22	15–23	
In-car NC _{0.02–1} , particles/cm ³			
Mean \pm SD	25,733 \pm 9210	26,453 \pm 9833	0.43
Range	13,045–69,162	12,146–70,698	
In-car temperature, °C			
Mean \pm SD	24.2 \pm 1.8	24.3 \pm 1.7	0.84
Range	23.1–25.1	23.1–25.2	
In-car relative humidity, %			
Mean \pm SD	77.2 \pm 2.1	77.9 \pm 2.2	0.81
Range	61.1–0.78.4	65.3–79.5	

4. Discussion

Although our study observed increases in in-room and in-car NC_{0.02–1} concentrations compared to background concentrations, the in-room and in-car NC_{0.02–1} concentrations were comparable and non-significantly different between volunteers with medical masks and cotton masks. Such findings are comparable with previous studies. *van der Sande et al. (2008)* recruited 28 healthy adult volunteers and 11 children. Each volunteer followed the same protocol (no activity-sit still, nod head, shake head, read aloud, stationary walk) wearing a Filtering Facepiece against Particles (FFP)-2 mask, a surgical mask, or a tea cloth mask for 10–15 min or 3 h (adult volunteers only). The concentration of NC_{0.02–1} was measured on both sides of the mask throughout the protocol. They found that all types of masks reduced aerosol exposure. However, FFP-2 masks were more efficient than surgical masks, which were more efficient than tea cloth masks. *Davies et al. (2013)* recruited 21 healthy volunteers to make face masks from cotton t-shirts. The number of microorganisms isolated from coughs of volunteers wearing cotton masks, surgical masks, or no mask was compared. The results showed that cotton and surgical masks could significantly reduce the number of microorganisms expelled by volunteers. However, the surgical mask was three times more effective in blocking transmission than the cotton mask.

Accordingly, these findings may suggest that cotton mask could be a potential substitute for medical mask for respiratory infection person in microenvironment with air conditioning. In addition, healthy people may daily use cotton mask in the community since cotton mask is washable and reusable. The shortage of disposable medical masks could be expected during a pandemic respiratory infection. The common fabric materials might be the potential option available for healthy people during a pandemic.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Kin-Fai Ho: Writing - review & editing. **Lian-Yu Lin:** Investigation. **Shao-Ping Weng:** Investigation. **Kai-Jen Chuang:** Conceptualization, Formal analysis, Writing - original draft, Project administration, Funding acquisition.

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